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TADIL TALES Templates:
Modeling Tactical Data Links for Command and Control Training

Track 2: Networks and Networking
Track 3: Modeling and Simulation
Track 7: Network Centric Experimentation and Operartions

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14. ABSTRACT
The US Air Force Distributed Mission Operations (DMO) concept continues to be the most successful application of Modeling and Simulation (M&S) for warfighter training. The program extends beyond individual pilot or crew training to include the entire real world operations spectrum. One important component of DMO is Command and Control (C2) training. Until recently, DMO C2 training requirements were difficult to meet because there were no accurate tactical data link simulation models. Now, C2 training requirements are met due to the recent development of modeling real world tactical data links. Development started with modeling Link 16, thus creating "Tactical Digital Information Link Technical Advice and Lexicon for Enabling Simulations" (TADIL TALES). TADIL TALES provides a simulated model for Link 16 using the Distributed Interactive Simulation (DIS) and High Level Architecture (HLA) simulation protocols. The "TADIL TALES" format has been verified by experiments conducted during Joint Expeditionary Force Experiment (JEFX) 04 and JEFX 06, and was incorporated into the recently approved Simulation Interoperability Standards Organization (SISO) standard SISO-STD-002. This standard is now widely used for Link 16 C2 training in DMO events, which now include the U.S. Army, Navy, Marines, and Joint Coalition warfighters. By using the TADIL TALES format, other C2 tactical data links can be modeled in the DIS and HLA simulation protocols at various fidelity levels. This paper describes the TADIL TALES formats for DIS and HLA and how other data links are being modeled, thus creating a new class of tactical data link simulation standards for DMO C2 warfighter training.

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The “TADIL TALES” format has been verified by experiments conducted during Joint Expeditionary Force Experiment (JEFX) 04 and JEFX 06, and was incorporated into the recently approved Simulation Interoperability Standards Organization (SISO) standard SISO-STD-002. This standard is now widely used for Link 16 C2 training in DMO events, which now include the U.S. Army, Navy, Marines, and Joint Coalition warfighters. By using the TADIL TALES format, other C2 tactical data links can be modeled in the DIS and HLA simulation protocols at various fidelity levels.

This paper describes the TADIL TALES formats for DIS and HLA and how other data links are being modeled, thus creating a new class of tactical data link simulation standards for DMO C2 warfighter training.

1. Introduction

Virtual Flag has incorporated distributed simulation technologies into various simulated training events, thus demonstrating the validity of recurring Command and Control (C2) virtual training. While the exercise was centrally controlled at the Distributed Missions Operations Center (DMOC), Warfighter-In-The-Loop (WITL) simulators from around the US participated in many VF training events. In addition to the Virtual WITL systems, DMOC began to incorporate intelligence and tactical data links. DMOC developed a model that send TADIL J messages using the Institute for Electrical and Electronic Engineers (IEEE) 1278.1a Distributed Interactive Simulation (DIS) standard Signal and Transmitter PDUs, thus creating "TACCSF-J".

Other simulation facilities had designed their own version using the DIS Signal and Transmitter PDUs. In fact, at least five different protocols were created. Tactical Data Link Technical Advice and Lexicon for Enabling Simulation (TADIL TALES) was created to model the Link 16 network as well as message exchange in DIS and High Level Architecture (HLA). This document was submitted as a proposed standard to the Simulation Interoperability Standards Organization (SISO), and in July 2006, it was approved as an official standard, SISO-STD-002.

2. SISO-STD-002 Description

SISO-STD-002 defines how to model a Link 16 network and exchange TADIL J messages using DIS Signal and Transmitter PDUs. The transmitter PDU adds 5 fixed modulation fields: Timeslot Allocation Mode, Transmitting Terminal Primary Mode, Transmitting Terminal Secondary Mode, Synchronization State, and Network Synchronization ID. These fields model some Link 16 network characteristics. The Signal PDU adds 160 bits after the Signal PDU Header and defined fields. Additional Link 16 network parameters that are modeled are: Network Participation Group, Net Number, Transmission Security, Message Security, Message Type Identifier, Timeslots, and Perceived Transmit Time. These fields provide the capability to adequately model a Link 16 network. The different fidelity levels allow the user to model as little or as much as necessary to meet C2 training requirements. For HLA, a Base Object Model was created which adds the required objects and interactions for Link 16 modeling and message exchange. The standard also includes DIS to HLA translation guidance.

3. Modeling Tactical Data Links

SISO-STD-002 became widely used, not only at the DMOC, but was adopted by the Combat Air Forces Distributed Missions Operations (CAF DMO) standards group. Several C2 simulation facilities across the US began using this standard, some even before the standard was officially approved. Since then, the need to model additional tactical data links has become apparent, such as Link 11/11B, Link 11/11B, Enhanced Position Location and Resolution System/Situational Awareness Data Link (EPLRS/SADL), and the Intelligence Broadcast Service – Interactive (IBS-I) and IBS – Surveillance (IBS-S). These tactical data links are used extensively in DMO C2 training, thus the requirement to develop tactical data link standards grew with DMO. Efforts are underway to create SISO standards for Link 11/11B and SADL, and are starting with IBS data. The proposed Link 11/11B and SADL standards have essentially the same structure as the Link 16 Transmitter PDUs, which are 64 bits of modulation parameter information. The same is true for the Signal PDU, which have proposed 160 bits of link specific parameters.

Base on this, the TADIL TALES "templates" could be used to create a class of tactical data link standards for DIS and HLA.

4. TADIL TALES TEMPLATES

The TADIL TALES templates have been proven in distributed experiments, and are used in distributed training events for Link 16. Furthermore, these models are used in the proposed standard for modeling Link 11/11B and SADL, and planed for use for IBS-I and IBS-S. These templates will enable other simulation facilities and organizations to either model tactical data links, or quickly set up tactical data link message exchange while allowing for future growth without extensive changes.

TADIL TALES Templates apply to PDU version 6 and earlier. Currently, IEEE 1278.1a is being updated, and some changes are to the Transmitter PDU that will impact the SISO-STD-002 and this proposal. Once IEEE 1278.1a is formally approved, then SISO-STD-002 and TADIL TALES Templates will be updated as well.

The TADIL TALES templates define a specific DIS Signal and Transmitter PDU structure, and HLA Base Object Models (BOMs) for data link modeling. These HLA BOMs define no new objects, but a new object

class that corresponds to the DIS Transmitter PDU. The HLA BOM also defines a family of interactions that support all tactical data implementation that corresponds to the DIS Signal PDU.

4.1 DIS Transmitter and Signal PDUs

The templates in Annex A show how the DIS Signal and Transmitter PDUs are modeled for tactical data link modeling and message transmission. The tactical data links will be distinguishable by TDL type. Additional enumerations can be added to the DIS Enumerated Bit Values for DIS document.

For the Transmitter PDU, the static fields will be populated as defined in 1278.1a-1995. 64 bits of modulation parameter data will be reserved for specific tactical data link modeling. If no tactical data link modulation parameters are defined, these shall be defined as padding. If modulation parameters are added later, no changes are required unless a modeling fidelity increase is necessary. Another option is to not include the 64 bits of padding, and setting the modulation parameters field to zero. That would set the modulation parameters to a variable length, thus adding flexibility to this template

For the Signal PDU, the static fields will be populated as defined in 1278.1a-1995. There will be an additional 160 bits to define the specific link characteristics. If no specific link characteristics are defined, then the 160 bits shall be padding for message transmission only. If modeling data are added later, no changes are required unless a modeling fidelity increase is necessary.

IEEE 1278.1a-1995 transmission rules for radios will apply. A transmitter/signal PDU pair or transmitter/signal/transmitter PDU wrap will be implemented as required.

4.2 HLA Base Object Model

The Link 16 BOM added a family of interactions that support future TDL implementation of other datalinks. For this paper, the acronym (LINK) will be used as a place holder for any tactical data link. For example, additional tactical data link interactions can be added to the (LINK)RadioSignal interaction, but can be designated as Link11RadioSignal or SADLRadioSignal. Complex data types and enumerations can also be added using the same method as for Link 16.

The TADIL TALES BOM assumes that:

1. The parent FOM contains all current DIS Transmitter PDU PDU records (not those associated with the PDU header) in accordance with IEEE 1278.1a as part of its object class hierarchy.
2. The parent FOM contains all current DIS Signal PDU PDU records (not those associated with the PDU header) in accordance with IEEE 1278.1a as part of its interaction class hierarchy.

Conventions within the TADIL TALES BOM in OMT 1.3 format will follow those adopted by the RPR FOM version 1.0 and 2.0. These conventions are:

1. All names have the initial letter of each word capitalized.
2. All enumeration names end in the text "Enum" followed by a number. The number indicates the number of bits in the enumerated value.
3. All complex data type names end in the text "Struct".

4.2.1. Object Class Data

The TADIL TALES BOMs define no new object classes. Instead the BOM shall define a single complex data type (LINK)TransmitterStruct that corresponds to the tactical data link modulation parameters in the DIS Transmitter PDU shown in Annex A. An attribute of this complex data type should be added to the object class in the parent FOM corresponding to the DIS Transmitter PDU. Modulation parameters of the Transmitter PDU shown in Annex A should map to the fields of the (LINK)TransmitterStruct complex data type attribute.

Parent object class fields are also modified such that they refer to the corresponding Transmitter PDU fields (see Assumption 1 in section 4.2).

NOTE: For a RPR FOM implementation, an attribute of the (LINK)TransmitterStruct complex data type should be added to the RadioTransmitter object class.

4.2.2. Interaction Class Data

The family of interactions is a hierarchy in which the BOM’s base class for this interaction is a generic class - the TDLBinaryRadioSignal interaction. This class is an empty class, contains no parameters, and is neither publishable nor subscribable. The specific parameters are properties of the various subclasses of this generic base class, and it is these subclasses that are published and subscribed to.

A tactical data link interaction shall be added as a subclass of the TDLBinaryRadioSignal interaction, and contain the tactical data link network header parameters. The (LINK)MessageRadioSignal interaction contains the tactical data link message data. Additional interactions shown in Annex A.3 define the other types of Link 16 messages.
The Link 16 BOM design is such that the TDLBinaryRadioSignal interaction becomes a subclass of the parent FOM's equivalent of the DIS Signal PDU

4.3 Adding Tactical Data Link BOMs to the RPR FOM

Adding a TDL BOM to the RPR FOM consists of three steps: adding the TDL Link Radio Signal interaction, adding the (LINK)TransmitterData structure, and adding the parameters necessary, as well as the associated enumerated and complex data types. Adding the interaction is the same for both RPR FOM version 1.0 and 2.0. The manner of adding the (LINK)TransmitterData structure differs between the two RPR FOM versions.

The TDLBinaryRadioSignal class shall be added as a subclass of the RawBinaryRadioSignal interaction class; this is done in order to allow access to the HostRadioIndex parameter in the RawBinaryRadioSignal interaction class. The HostRadioIndex parameter will tie the TDL message to a specific Host and Radio Transmitter.

The (LINK)RadioSignal interaction class is added as a subclass of a new interaction class, the TDLBinaryRadioSignal interaction, which itself is a subclass of the RPR FOM's RawBinaryRadioSignal interaction class as shown in Annex B.

4.4 DIS to HLA Translations

TADIL TALES Templates will follow the DIS to HLA translations algorithms provided in SISO-STD-002 Appendix C. For the lower fidelity, message exchange only protocols, the translations will require byte tables for the data only, and link characteristics can be added when available.

5. TADIL TALES TEMPLATES Benefits

There are many benefits to adopting the TADIL TALES TEMPLATES for tactical data link modeling in DIS and HLA. First, it is a low cost solution to send tactical data link messages because code reuse can be applied when modeling more than one tactical data link. Second, tactical data link message transmission can be built very quickly, due to code reuse. And third, if an organization or service decides to enhance the DIS or HLA fidelity, they can use the 64 bits of padding in the Transmitter PDU and 160 bits of padding in the Signal PDU. If other services or simulation centers have implemented the template but not any link modeling, interoperability is still possible because those sites will ignore the higher fidelity modeling, thus ensuring that different DIS or HLA models will not be developed, as was the case for Link 16.

6. Conclusions

TADIL TALES Templates makes available a standard model for current and future tactical data links. These templates can be implemented quickly, and gives the option, not requirement, for simulations to change when higher fidelity models are defined. The higher fidelity standards will have fidelity/interoperability between simulations, much like the SISO-STD-002 standard for Link 16.

7. Acknowledgements

We thank the DMOC for sponsoring this paper and supporting SISO participation for the Link 16 DIS and HLA standard. We also thank the SISO Link 16 PDG Officers and members, ballot members, and their respective sponsors. Additionally, we extend our thanks to AFAMS and Air Combat Command (ACC) for experimentation support, and Mr. Don Neal, Modeling and Simulation Lead for JEFX 04 for accepting the DIS J experiment and his support. Also, we thank Northrop Grumman, Lockheed Martin Corporation, Arctic Slope Regional Corporation (ASRC) Communications, and Scientific Research Corporation (SRC). From DMOC, we thank Chief Engineer Mr. Tom Brown and DMOC's Commanders that continuously support this project throughout the years: Col John "Boomer" Henry, Col. Ron "Opie" Wiegand, Lt. Col. Gordon "Gordo" Phillips, and Lt. Col. Donald "Drex" Dreschler.

8. Author Biography

Mr. Sorroche is a Senior Engineer with Arctic Slope Regional Corporation Communications (ASRCC), and has 18 years professional experience; 11 years experience in the Modeling and Simulation field. He currently works at the DMOC and has been the Engineering lead for the DMOC for JEFX 06, JEFX

04, Millennium Challenge 02, JEFX 2000, JEFX 99, EFX 98, and many Blue Flag and Virtual Flag exercises. He is the Chair for the SISO Tactical Data Links Product Support Group, the Link 11/11B Product Development Group Chair, and the SISO Liaison for the NATO Tactical Data Link Interoperability Testing Syndicate. Mr. Sorroche is a co-recipient of the Fall 2002 SIWZIE Award for paper 02F-SIW-119 titled “TADIL TALES.”, and a co-recipient of the Spring 2006 SIWZIE Award for paper 06S-SIW-074 titled “A Mixed Architecture for Joint Testing”. He has Bachelors and Masters of Science Degrees in Electrical Engineering from New Mexico State University. He is a member of Tau Beta Pi and Eta Kappa Nu Honor Societies.

ANNEX A: TADIL TALES DIS TEMPLATES

TADIL TALES Template Transmitter PDU

Field Size (bits)	Transmitter PDU Fields			Description*
96	PDU Header	Protocol Version	8 bit enumeration	
		Exercise ID	8 bit unsigned integer	
		PDU Type	8 bit enumeration	
		Protocol Family	8 bit enumeration	
		Timestamp	32 bit unsigned integer	
		Length	16 bit unsigned integer	
		Padding	16 bits unused	
48	Entity ID	Site	16 bit unsigned integer	
		Application	16 bit unsigned integer	
		Entity	16 bit unsigned integer	
16	Radio ID		16 bit unsigned integer	TDL Radio ID transmitting the signal.
64	Radio Entity Type	Entity Kind	8 bit enumeration	
		Domain	8 bit enumeration	
		Country	16 bit enumeration	
		Category	8 bit enumeration	Tactical Data Link Enumeration IAW Ref. 4
		Nomenclature Version	8 bit enumeration	
		Nomenclature	16 bit enumeration	
8	Transmit State		8 bit enumeration	
8	Input Source		8 bit enumeration	8 - Digital Data Device
16	Padding		16 bits unused	
192	Antenna Location	X component	64 bit floating point	
		Y component	64 bit floating point	
		Z component	64 bit floating point	
96	Relative Antenna Location	x component	32 bit floating point	
		y component	32 bit floating point	
		z component	32 bit floating point	
16	Antenna Pattern Type		16 bit enumeration	
16	Antenna Pattern Length		16 bit unsigned integer	
64	Frequency		64 bit unsigned integer	Set to Center Frequency
32	Transmit		32 bit floating point	Set to Transmission Frequency Bandwidth, 3 db down

TADIL TALES Template Transmitter PDU

Field Size (bits)	Transmitter PDU Fields			Description*
	Frequency Bandwidth			
32	Power		32 bit floating point	Power in dBm
64	Modulation Type	Spread Spectrum	16 bit Boolean array	Bit 1 set to 1: if Frequency Hopping used. All bits set to 0 if not used
		Major	16 bit enumeration	Tactical Data Link Enumeration IAW SISO DIS EBV Document
		Detail	16 bit enumeration	Tactical Data Link Enumeration IAW SISO DIS EBV Document
		System	16 bit enumeration	Tactical Data Link Enumeration IAW SISO DIS EBV Document
16	Crypto System		16 bit enumeration	Tactical Data Link Enumeration IAW SISO DIS EBV Document
16	Crypto Key ID		16 bit unsigned integer	
8	Length of Modulation Parameters		8 bit unsigned integer	Set as required
24	Padding		24 bits unused	
	Modulation Parameters	Tactical Data Link Characteristic	Set as required for Tactical Data Link Parameters. For TDL message exchange only, this field can be 64 bits of padding.	Integer, Floating Point, or Enumeration

TADIL TALES TEMPLATE SIGNAL PDU

<table>
<tr><th>Field Size (bits)</th><th colspan="3">Signal PDU Fields</th><th>Valid Range</th><th>Description</th></tr>
<tr><td rowspan="7">96</td><td rowspan="7">PDU Header</td><td>Protocol Version</td><td>8 bit enumeration</td><td></td><td></td></tr>
<tr><td>Exercise ID</td><td>8 bit unsigned integer</td><td></td><td></td></tr>
<tr><td>PDU Type</td><td>8 bit enumeration</td><td></td><td></td></tr>
<tr><td>Protocol Family</td><td>8 bit enumeration</td><td></td><td></td></tr>
<tr><td>Timestamp</td><td>32 bit unsigned integer</td><td></td><td></td></tr>
<tr><td>Length</td><td>16 bit unsigned integer</td><td></td><td></td></tr>
<tr><td>Padding</td><td>16 bits unused</td><td></td><td></td></tr>
<tr><td rowspan="3">48</td><td rowspan="3">Entity ID</td><td>Site</td><td>16 bit unsigned integer</td><td></td><td></td></tr>
<tr><td>Application</td><td>16 bit unsigned integer</td><td></td><td></td></tr>
<tr><td>Entity</td><td>16 bit unsigned integer</td><td></td><td></td></tr>
<tr><td>16</td><td>Radio ID</td><td></td><td>16 bit unsigned integer</td><td></td><td>Shall contain the ID of the Tactical Data Link radio or terminal transmitting the signal.</td></tr>
<tr><td>16</td><td>Encoding Scheme</td><td></td><td>16 bit enumeration</td><td></td><td>Bits 0-13 shall contain the number of Tactical Data Link words not including the TDL header. Bits 14-15 shall contain the value 1 to indicate an encoding class raw binary data</td></tr>
<tr><td>16</td><td>TDL Type</td><td></td><td>16 bit enumeration</td><td></td><td>Tactical Data Link Enumeration IAW SISO DIS EBV Document</td></tr>
<tr><td>32</td><td>Sample Rate</td><td></td><td>32 bit integer</td><td></td><td>This field shall be set to 0</td></tr>
<tr><td>16</td><td>Data Length</td><td></td><td>16 bit integer</td><td></td><td>This field shall contain the length of tactical data in bits beginning after the samples field.</td></tr>
<tr><td>16</td><td>Samples</td><td></td><td>16 bit integer</td><td></td><td>This field shall be set to 0</td></tr>
<tr><td>160</td><td>TDL Signal PDU Fields</td><td colspan="4">Use 160 bits to describe Tactical Data Link Characteristics. Each field can be divided into 8, 16, or 32 bits of data, but must meet IEEE 1278.1a-1995 requirements for byte alignment. For message transfer only, the 160 bits can be defined as padding.
.</td></tr>
<tr><td colspan="2">Message Data</td><td colspan="4">Arrays of octets</td></tr>
<tr><td colspan="3">Padding</td><td>Signal PDU C2 Padding to doubleword boundary IAW IEEE 1278.1a</td><td></td><td>Padding (if needed) to increase total PDU size to a multiple of 32 bits.</td></tr>
</table>

ANNEX B: TADIL TALES HLA BOM TEMPLATES

TADIL TALES Interaction Table

Interaction1	Interaction2	Interaction3	Interaction4	Interaction5
RadioSignal	ApplicationSpecifcRadioSignal			
	DatabaseIndexRadioSignal			
	EncodedAudioRadioSignal			
	RawBinaryRadioSignal	TDLBinaryRadioSignal	LINKRadioSignal	LINK_Message

TADIL TALES Complex Datatypes in RPR-FOM 1.0

Complex Datatype	Field Name	Datatype	Cardinality
ModulationStruct	SINCGARModulation[52]	SINCGARSModulationStruct	0-1
	LINKTransmitterData[56]	LINKTransmitterStruct	0-1

TADIL TALES Enumerated Values in RPR-FOM 1.0

Identifier	Enumerator	Representation
RFModulationSystemTypeEnum16	Other	0
	Generic	1
	HQ	2
	HQII	3
	HQIIA	4
	SINCGARS	5
	CCTT_SINCGARS	6
	LINK	8 . . . .
	LINK	XX

TADIL TALES Complex Datatypes in RPR-FOM 2.0

Complex Datatype	Field Name	Datatype	Cardinality
SpreadSpectrumStruct	SpreadSpectrumType	SpreadSpectrumEnum16	1
	Padding	Octet	2
	SINCGARModulation[52]	SINCGARSModulationStruct	0-1 (SpreadSpectrumType = SINCGARSFrequencyHop)
	LINKTransmitterData[56]	LINKTransmitterStruct	0-1 (SpreadSpectrumType

			= LINK_SpectrumType)

TADIL TALES Enumerated Values in RPR-FOM 2.0

Identifier	Enumerator	Representation
RFModulationSystemTypeEnum16	Other	0
	Generic	1
	HQ	2
	HQII	3
	HQIIA	4
	SINCGARS	5
	CCTT_SINCGARS	6
	JTIDS_MIDS	8
SpreadSpectrumEnum16	None	0
	SINCGARSFrequencyHop	1
	LINK_SpectrumType	2